OPTICAL CLEARING OF EYE TISSUES

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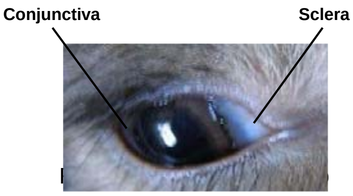
Motivation

It is well known that diagnostics and treatment of many diseases of the human eye is connected with monitoring of glucose content. However, in spite of numerous investigations dealing with transport of the metabolite within biological tissue the problem of estimating the diffusion coefficient of glucose in ocular tissues has not been studied in detail

Goal of the study is to measure the diffusion coefficient of glucose in rabbit eye sclera and conjunctiva



Materials and methods

- Experimental setup

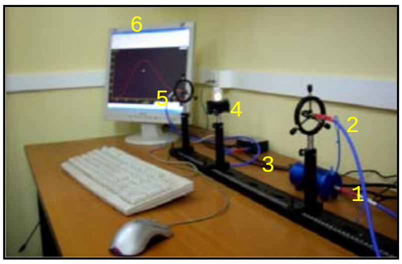


Fig.2. Scheme of experimental setup:1-light source - halogen lamp HL-2000; 2-fiber delivering light to the tissue simple; 3-multichannel spectrometer–USB-4000 (Ocean Optics, USA); 4-cuvette with the sample;5-fiber collecting light passed through the sample; 6-PC

- For this study in tens rabbit eye sclera and conjunctiva samples were used. The samples were obtained from autopsy and kept in saline at temperature 4-5°C during 24 hour until spectroscopic measurements
- Measurement of collimated transmittance have been performed using a commercially available spectrometer USB-4000 (Ocean Optics, USA) in the spectral range 500-900 nm
- All measurements were performed at room temperature (about 20°C)
- Commercially available 40% aqueous solution of glucose was used. Refractive index of the solution was 1.391. It was measured using Abbe refractometer at wavelength 589 nm

Glucose diffusion coefficient estimation

Determination of glucose concentration within sclera and conjunctiva has been performed using the assumption:

$$T \sim \exp(-\mu_s l)$$

$$\mu_s = N\frac{\pi^2 a x^3}{8}\left(m^2-1\right)^2\left(1+\frac{2}{\left(m^2+1\right)^2}\right)(1-\varphi)^3/(1+\varphi)$$

$$x = 2\pi a n_I/\lambda \qquad m = n_s/n_I \qquad n_I = n_{I0}(1-C)+n_c C$$

T is the collimated transmittance; μ_s is the scattering coefficient; *l* is the tissue thickness; *N* is the numerical concentration of the tissue scatterers; *a* is the scatterers radius; n_s = 1.411 is the refractive index of the scatterers; n_I is the refractive index of interstitial fluid of the tissue; and φ is the volume fraction of the scatterers; n_{I0} = 1.332 is the refractive index of interstitial fluid of tissue before glucose diffusion; n_c is the refractive index of the glucose solution; and *C* is the concentration of glucose within tissue.

Penetration of glucose in eye conjunctiva was described in the framework of the free diffusion model

$$\frac{\partial C(x,t)}{\partial C} = D\frac{\partial^2 C(x,t)}{\partial x^2} \qquad \textit{Diffusion equation}$$

$$C(0,t)=C_0 \text{ and } C(l,t)=C_0 \qquad \textit{Boundary conditions}$$

$$C(x,0)=0 \qquad \textit{Initial condition}$$

Solution of the diffusion equation for slab with thickness *l* at moment *t* with the boundary and the initial conditions has the form

$$C(t)=C_0\left(1-\frac{8}{\pi^2}\sum_{i=0}^{\infty}\frac{1}{(2i+1)^2}\exp\left(-(2i+1)^2 t\pi^2 D/l^2\right)\right)$$

C (*t*) is the volume-averaged concentration of the glucose within tissue sample, g/ml; *D* is diffusion coefficient, cm²/sec.

In a first order approximation, solution of the diffusion equation can be reduced to the form

$$C(t) \approx C_0\left(1-\exp(-t/\tau)\right)$$

$$\tau = \frac{l^2}{\pi^2 D} \qquad D = pD_0 = (1-\varphi)D_0$$

τ is diffusion time constant, sec; *p* is porosity coefficient of conjunctiva; φ is volume fraction of scatterers; and D_0 is glucose diffusion coefficient within interstitial fluid, cm²/sec.

Results

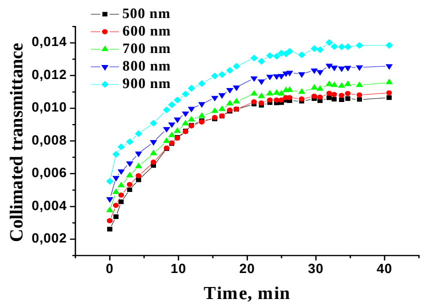


Fig.3. The time-dependent transmittance of the eye conjunctiva measured at different wavelength concurrently with administration of glucose solution

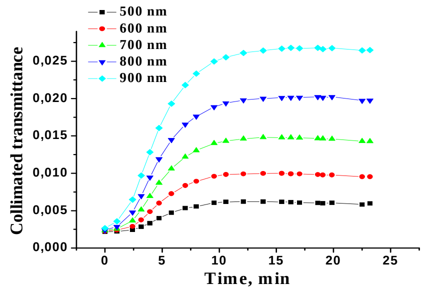


Fig.4. The time-dependent transmittance of the eye sclera measured at different wavelength concurrently with administration of glucose solution

The average values of glucose diffusion coefficient in rabbit eye conjunctiva and sclera are $(3.2\pm3.9)\times10^{-7}$ and $(9.38\pm6.84)\times10^{-7}$ cm²/sec, respectively.

Summary

Obtained results have shown that application of 40%-glucose solution as a clearing agent allows to control by sclera and conjunctiva optic parameters

Thus, an action of the solution is increase of collimated transmittance and decrease of scattering

This achievement is very important for optical diagnostics approaches

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